

FRAMEWORK DOCUMENT for DISTRIBUTION TRANSFORMER ENERGY CONSERVATION STANDARDS RULEMAKING

Draft for Public Comment

November 1, 2000

1. INTRODUCTION

The purpose of this document is to describe the procedural and analytical approaches the Department of Energy (hereafter called the Department or DOE) anticipates using to evaluate the establishment of energy conservation standards for distribution transformers. As described in more detail below, the procedure for developing energy conservation standards entails several rounds of analysis and multiple consultations with interested parties. This document is provided to inform and facilitate interested parties' involvement in the rulemaking process. It is not a definitive statement with respect to any issue to be determined during the process. Section 1 provides an overview of the program, Section 2 discusses the energy conservation standard rulemaking process, Section 3 discusses the analyses to be done, Section 4 raises issues of concern and some relevant background on distribution transformers is presented in Section 5. Information regarding the distribution transformer standards rulemaking will be maintained on the DOE website at http://www.eren.doe.gov/buildings/codes_standards/applbrf/dist_transformer.html.

1.1 COMMERCIAL EQUIPMENT EFFICIENCY PROGRAM

The Energy Policy and Conservation Act (EPCA) of 1975, Pub. L. 94-163, established an energy conservation program for major household appliances. The National Energy Conservation Policy Act of 1978, Pub. L. 95-619, amended EPCA to add Part C of Title III, which established an energy conservation program for certain industrial equipment. The amendments to EPCA, in the Energy Policy Act of 1992 (EPACT), Public Law 102-486, included amendments that expanded Title III of EPCA to include certain commercial equipment, including distribution transformers, the focus of this document.

The Department of Energy, Office of Energy Efficiency and Renewable Energy, Office of Building Research and Standards (BRS) conducts the program that develops and promulgates equipment energy conservation standards and has overall responsibility for rulemaking activities for distribution transformers in fulfillment of the law. The Department has contracts with Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory and Arthur D. Little, Inc. to provide technical, analytical and managerial support in conducting these activities.

1.2 OVERVIEW OF THE STANDARDS SETTING PROCESS

While this document is focused on the Department's approach to evaluating energy conservation standards for distribution transformers, the energy conservation standards process is the culmination of a larger process. As illustrated by Figure 1, the process was set in motion by the EPACT of 1992.

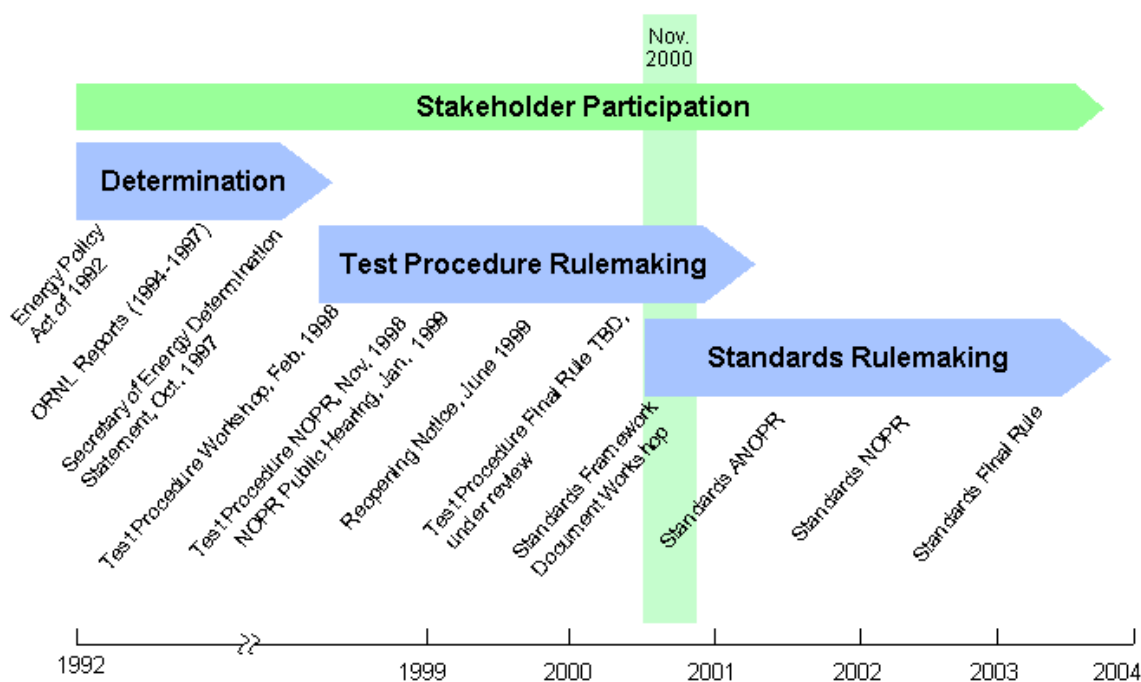


Figure 1. Principal procedural steps in the distribution transformer standards setting process

The first stage of the larger process was the determination that energy conservation standards appear to be technologically feasible and economically justified, and likely to result in significant energy savings. Section 1.2.2 below summarizes the history of the determination.

The second stage of the larger process is establishment of test procedures that would be used to measure the energy conservation performance of distribution transformers. Section 1.2.3 below summarizes the history and status of the test procedure stage of the larger process. The third stage, and the focus of this document, is the evaluation of the energy conservation standards.¹ Section 2 of this document describes the energy conservation standards setting process.

¹The last stage, which is not discussed in this document, is development of labeling requirements for distribution transformers. Labeling requirements would be set after the energy conservation standards were established.

1.2.1 Stakeholder Participation

As also indicated by Figure 1, the Department considers stakeholder participation a very important part of the process for setting energy conservation standards. The Department actively encourages the participation and interaction of all stakeholders at all stages of the process. Early and frequent interactions among stakeholders provide a balanced discussion on critical information required to conduct the analysis to support any standards.

Stakeholders include manufacturers and consumers of distribution transformers, energy efficiency and environmental advocates, state agencies, federal agencies and other groups or individuals with an interest in the standards.

Both the test procedures and the energy conservation standards are being developed through the rulemaking process, which involves formal public notifications that are common to the Department's rulemaking activities. For the transformer energy conservation standards rulemaking, the Department will employ the rulemaking procedures set forth in Part B of Title III of EPCA and in Appendix A to Subpart C of 10 CFR 430, "Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products" (the Process Rule), (61 FR 36981, July 15, 1996).

In an energy conservation standards rulemaking, the first of the rulemaking notices is an Advance Notice of Proposed Rulemaking (ANOPR), which is designed to facilitate extensive and early public participation and to select candidate standard levels for further analyses. The ANOPR is followed by the publication of a Notice of Proposed Rulemaking (NOPR) which will propose energy conservation standards. The completion of the rulemaking process is a Notice of Final Rulemaking which places the energy conservation standards in the Code of Federal Regulations.

The process provides numerous opportunities for stakeholder involvement. Specifically, the Department intends to request public comments on the ANOPR, with a 75-day public comment period and at least one public hearing or workshop, and public comments on the NOPR, with a 75-day public comment period and at least one public hearing or workshop. These activities will be summarized and published in rulemaking notices that appear in the *Federal Register* and on the Department's website. Technical Support Documents (TSD) also will be prepared in conjunction with the notices and distributed for stakeholder review and comment in conjunction with publication of those notices. The above notices and activities associated with them are discussed in Section 2.

In addition, the Department will elicit stakeholder participation prior to these notices and during analyses prepared in support of the notices. The first of these opportunities will be the framework meeting to discuss the information contained in this document, and the Department will also seek written comments on this document. Section 3 of this document summarizes the Department's planned approach to conducting the analyses anticipated to support the rulemaking. Section 4 gives a background on distribution transformers regarding the energy savings opportunities and Section 5 describes a number of issues of concern that the Department believes are important to the overall rulemaking, why these issues are considered important, and possible alternatives and approaches that might be pursued in addressing these issues. The Department solicits input from stakeholders about these issues as well as any other issues that may be important to this rulemaking.

1.2.2 Determination

The first step in developing energy conservation standards was the Secretarial determination that, "Based on its analysis of the information now available, the Department has determined that energy conservation standards for transformers appear to be technologically feasible and economically justified, and are likely to result in significant savings" 62 *FR* 54809 (October 22, 1997). It is important to note that the determination is provisional because the determination stated, "Although all of the cases analyzed are technologically feasible and have significant energy savings, and at least two of these cases appear to be economically justified, it is still uncertain whether further analyses will reconfirm these findings. For example, the Department has not assessed the potential adverse impacts of a national standard on manufacturers or individual categories of users." 62 *FR* 54816. As outlined in this document, the Department plans to perform analyses of the impacts of possible standards on manufacturers and consumers.

The Secretary's Determination was based, in part, on analyses conducted by the Oak Ridge National Laboratory (ORNL). In July 1996, ORNL published a report, entitled "*Determination Analysis of Energy Conservation Standards for Distribution Transformers, ORNL-6847*" which assessed several options for setting energy conservation standards. That report was based on information from annual sales data, average load data, and surveys of existing and potential transformer efficiencies that were obtained from several organizations.

In September 1997, ORNL published a second report, entitled *Supplement to the 'Determination Analysis' (ORNL-6847) and Analysis of the NEMA Efficiency Standard for Distribution Transformers, ORNL-6925*. The purpose of this second ORNL report was to assess the suggested efficiency levels contained in the then newly published NEMA Standards Publication No. TP 1-1996, "Guide for Determining Energy Efficiency for Distribution Transformers," along with the efficiency levels previously considered by the Department in the determination study, using the more accurate analytical model and transformer market and loading data developed subsequent to the publication of the original ORNL report. Downloadable versions of the above reports are available on the DOE web site at http://www.eren.doe.gov/buildings/codes_standards/applbrf/dist_transformer.html.

1.2.3 Test Procedure

The next step in the process is development of test procedures. The test procedure development for distribution transformers was initiated on February 10, 1998, when the Department held a public workshop attended by representatives from NEMA, manufacturers, utilities, Federal and state agencies, the Canadian government, and other interested parties. Draft test procedures based on recognized industry standards were presented as a basis for discussion. A transcript of the public workshop is available at the DOE Freedom of Information Reading Room.

During 1998, NEMA developed and published NEMA Standard TP 2-1998, "Standard Test Method for Measuring the Energy Consumption of Distribution Transformers." This publication attempted to present in a single document the ANSI/IEEE recognized industry standards for testing transformer efficiency. It also presented a method to demonstrate compliance with the suggested efficiency levels of NEMA Standard TP 1. Comments received at the workshop, written statements and NEMA Standard TP 2-1998 were all considered in preparing a NOPR for distribution transformer test procedures. 63 FR 63360 (November 12, 1998). The NOPR proposed that DOE would incorporate, as its test procedure for transformer efficiency, either portions of the recognized industry testing standards or NEMA Standard TP 2-1998. The Department also proposed in the NOPR a definition of "distribution transformer," which would delineate the transformers covered by any final test procedures.

DOE held a public hearing on January 6, 1999, on the proposed test procedure rule. Based on the comments received, DOE concluded that a number of significant issues had been raised that required additional analysis. On June 23 1999, the Department reopened the comment period on the proposed rule to provide an opportunity for additional public comment on the information provided at the public hearing and its implications regarding the proposed test procedures and the policy options then under consideration by the Department. 64 FR 33431 (June 23, 1999). The significant issues included: the suitability of NEMA Standard TP 2-1998 to be adopted as the DOE test procedure; transformers covered under the definition of "distribution transformer;" and the appropriateness of proposed sampling plans for demonstrating compliance. In reviewing the test procedure rulemaking record and preparing the final rule, representatives of the Department developed concerns about whether NEMA Standard TP 2-1998 had the level of detail required for a mandatory Federal test procedure that possibly might have to be legally enforced. The Department is attempting to clarify NEMA Standard TP 2-1998 at this time, and understands that NEMA has agreed to consider revisions to TP 2 suggested by the Department. The Department intends to assess such revisions by means of a limited reopening of the test procedure rulemaking record. The Department expects to publish the test procedure final rule before publishing the NOPR on energy conservation standards.

2. DEVELOPMENT OF ENERGY CONSERVATION STANDARDS FOR DISTRIBUTION TRANSFORMERS

This chapter summarizes the administrative processes the Department will employ to consider energy conservation standards for distribution transformers. The Process Rule sets forth guidelines that are broadly relevant to many consumer products but are described here to the extent they are applicable to developing energy conservation standards for distribution transformers.

As noted in Sect. 1.2, the formal rulemaking process for development of energy conservation standards includes three notices: the Advance Notice of Proposed Rulemaking (ANOPR), the Notice of Proposed Rulemaking (NOPR), and the Notice of Final Rulemaking. The activities that are relevant to the development of energy conservation standards for distribution transformers leading to each of these notices and the relationships among them are described below.

2.1 ADVANCE NOTICE OF PROPOSED RULEMAKING

As part of its initial rulemaking activities, the Department will identify the product design options or efficiency levels that will be analyzed in detail and those that can be eliminated from further consideration. This process includes a preliminary market and technology assessment (see Sect. 3.2) and a screening process (see Sect. 3.3). These activities include consultations with interested parties and independent technical experts who can assist with identifying the key issues and design options or efficiency levels to be considered.

The technologically feasible design options or efficiency levels that are not eliminated in the screening process are considered further. The principal activities undertaken during this stage are: an engineering analysis (see Sect. 3.4), a life-cycle cost analysis (see Sect. 3.5), and preliminary national energy savings and net present value analyses (see Sect. 3.7).

The results of the analyses will be made available on the Department's website for review and the Department will consider comments on them. This review and comment process may result in revisions to the analyses. If appropriate, public workshops may be conducted to enhance the exchange of information and comments. This analytical process culminates with the selection of candidate standard levels, if any, that will be considered for the Proposed Rule. The candidate standard levels are contained in the ANOPR which DOE publishes in the *Federal Register*. The ANOPR specifies the candidate standard levels that are chosen for further analysis but does not propose a particular standard. The ANOPR also presents the results of the engineering analysis and the preliminary analyses of consumer life-cycle costs, national net present value, and national energy savings. The Department will also make available a TSD containing the details of all the analyses performed to this point.

Selection of candidate standard levels is based on costs and benefits of design options or efficiency levels. Design options or efficiency levels which have payback periods that exceed the average life of the product or which cause life-cycle cost increases relative to the base case would generally not be selected as candidate standard levels.

The range of candidate standard levels will typically include

- the most energy efficient level;
- the level with the lowest life-cycle cost;
- a level with a payback period of not more than 3 years; and
- candidate standard levels that incorporate noteworthy technologies or fill in large gaps between efficiency levels of other candidate standard levels.

After the publication of the ANOPR, there is a 75-day public comment period and at least one public hearing or workshop. On the basis of comments received, DOE may revise the analysis or the candidate standard levels. If major changes are required, interested parties and technical experts will be given an opportunity to review the revised analyses.

2.2 NOTICE OF PROPOSED RULEMAKING

After the ANOPR, DOE will conduct further economic impact analyses of the candidate standard levels. These analyses may include refinements of the analyses done for the ANOPR and also will include: a consumer sub-group analysis (see Sect. 3.6), a manufacturer impact analysis (see Sect. 3.8), a utility impact analysis (see Sect. 3.9), an environmental analysis (see Sect. 3.10), and net national employment impacts (see Sect. 3.11).

The results of all the analyses will be made available on the Department's website for review and the Department will consider comments on them. This review and comment process may result in revisions to the analyses. If appropriate, public workshops may be conducted to enhance the exchange of information and comments. This analytical process culminates with the selection of proposed standard levels, if any, that will be presented in the NOPR. The NOPR, published in the *Federal Register*, will document the evaluation and selection of any proposed standards. For each product class, the Department also will identify the maximum improvement in energy efficiency or maximum reduction in energy use that is technologically feasible and, if the proposed standards would not achieve these levels, the Department will identify the reasons for proposing different standards. The NOPR also will present the results of all the analyses. The Department will also make available a TSD containing the details of all the analyses.

The Department considers many factors in selecting proposed standards. These factors include the selection policies established by statute and the many benefits, costs and impacts of the standards shown by the analyses. Additionally, the Department encourages stakeholders to develop joint recommendations for standard levels. If the Department receives a joint recommendation from a representative group of interested parties, such a recommendation will be strongly considered in the decision process to select the proposed standard level.

The NOPR is followed by a 75-day public comment period that includes at least one public hearing or workshop; revisions to the analyses may result from the public comments. On the basis of the public comments, DOE reviews the proposed standard and impact analyses and makes modifications as necessary. If major changes to the analyses are required at this stage, interested parties and experts will be given an opportunity to review the revised analyses.

2.3 NOTICE OF FINAL RULEMAKING

The final step in the rulemaking process would be the publication of a Notice of Final Rulemaking in the *Federal Register*. The Final Notice promulgates standard levels based on the record and explains the basis for the selection of those standards. It is accompanied by the final TSD.

3. ANALYSES FOR RULEMAKING

This section introduces the analyses that are to be conducted during the standards setting process to provide information to the Department to inform its selection of proposed standards.

3.1 INTRODUCTION

The analytical components of the standards setting process are summarized in Figure 2. The focus of this figure is the center column, identified as analysis. The columns labeled “key inputs” and “key outputs” are intended to indicate how the analyses fit into the rulemaking process, and how the analyses relate to each other. Key outputs are analytical results that feed directly into the standard-setting process. Dotted lines connecting analyses indicate types of information that feed from one analysis to another. Key inputs are the types of data and information that are required by the analyses. Some key inputs exist in public databases, some will be collected from stakeholders or others with special knowledge, and some of the key inputs will be developed by the project team to support the standards-setting process.

Ultimately, the Department intends to select the distribution transformer energy conservation standards that achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified. In the context of this process, economic justification includes consideration of the economic impacts on domestic distribution transformer manufacturers and consumers of distribution transformers, national benefits including environmental, issues of consumer utility and impacts from any lessening of competition. Many of the analyses are aimed at answering questions about these aspects of economic justification.

The remainder of this chapter describes the principal analyses noted in Figure 2.

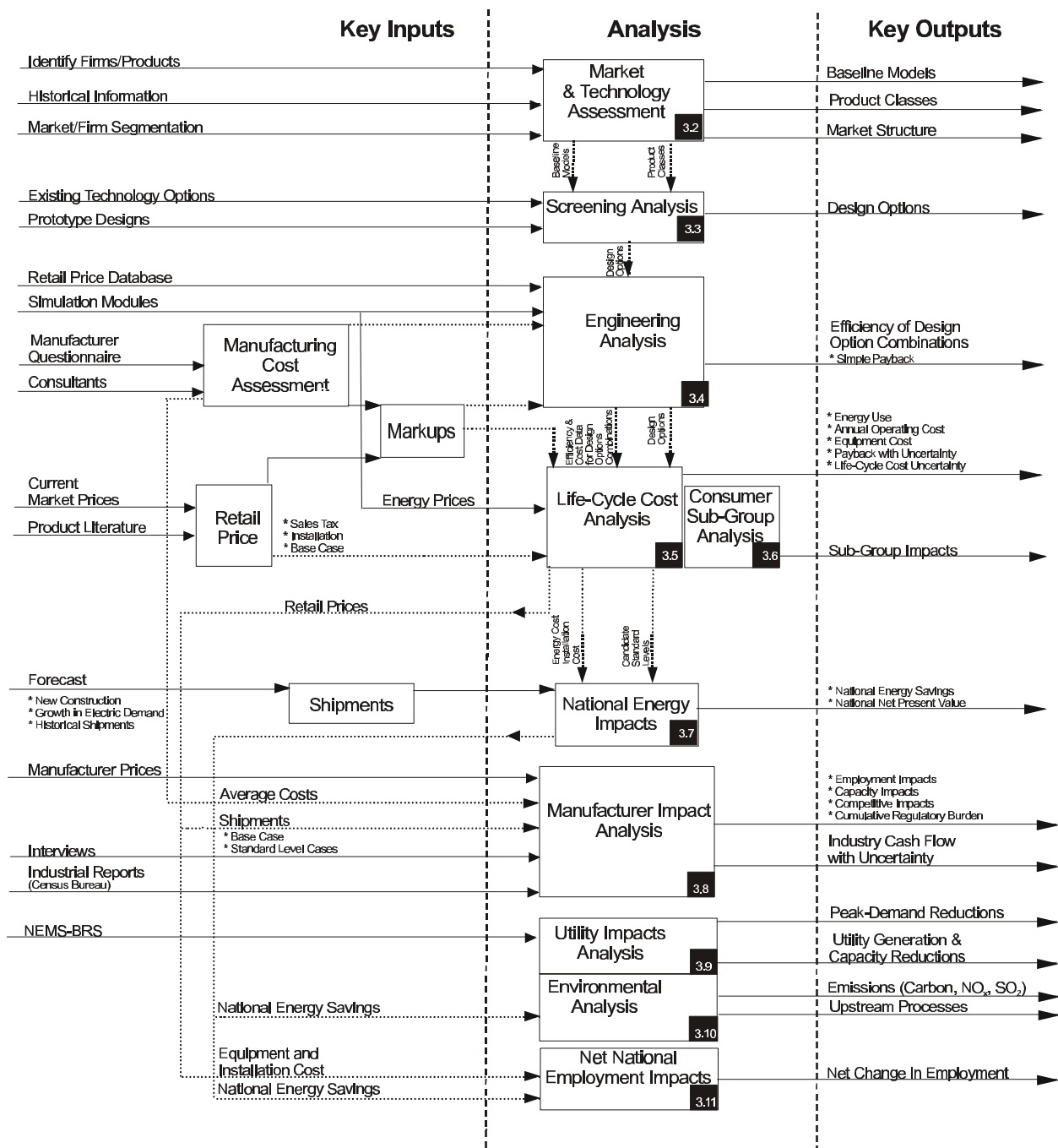


Figure 2. Flow diagram of analyses for distribution transformer energy conservation standards.

3.2 MARKET AND TECHNOLOGY ASSESSMENT

The Market and Technology Assessment will provide information about the distribution transformer industry that will be used throughout the standards development process, and at the outset to determine product classes, to develop the baseline models, and to identify potential design options or efficiency levels for each of the distribution transformer product classes.

The Department has collected preliminary information regarding the distribution transformer industry [Barnes, et al., 1996, Determination Analysis of Energy Conservation Standards for Distribution Transformers, ORNL-6847, and Barnes, et al., 1997, Supplement to the "Determination Analysis" (ORNL-6847) and Analysis of NEMA Efficiency Standard for Distribution Transformers, ORNL-6925]. This information will be updated, as needed, to characterize the distribution transformer industry.

Additional market data will be collected from publicly available sources, industry trade associations such as the National Electrical Manufacturers Association (NEMA) and through interviews with manufacturers, distributors and others. These interviews will provide insights and information to help structure future analyses. Manufacturer answers to the interview questions are expected to be valuable in projecting the effects of standards on the entire transformer industry, and on the potential impacts of standards on both individual firms and particular categories of firms.

3.3 SCREENING ANALYSIS

The purpose of the screening analysis is to identify and evaluate those design options or efficiency levels that could improve distribution transformer efficiency and to determine which to evaluate in detail in the engineering analysis and which to evaluate no further during this rulemaking. This screening process includes consultations with interested parties and independent technical experts who can assist with identifying the key issues and design options or efficiency levels. The screening analysis also discusses the criteria for eliminating certain design options or efficiency levels from further consideration. By comparing the design options or efficiency levels against these criteria, the Department eliminates from further analysis those options or efficiency levels that are not sufficiently developed or have characteristics that make them technologically unsuitable for consideration in the rulemaking. The factors for screening design options and efficiency levels include:

- technological feasibility. Technologies incorporated in commercial products or in working prototypes are considered technologically feasible.
- practicability to manufacture, install, and service. If mass production of a technology in commercial products and reliable installation and servicing of the technology could be achieved on the scale necessary to serve the relevant market at the time of the effective date of the standard, then that technology is considered practicable to manufacture, install and service.
- adverse impacts on a product's usefulness or availability to consumers.
- adverse impacts on health or safety.

The design options or efficiency levels that are not eliminated in this screening process are considered in the engineering analysis.

3.4 ENGINEERING ANALYSIS

After the screening analysis, the Department performs an engineering analysis on the options or efficiency levels that were not eliminated. The purpose of the engineering analysis is to estimate the relationship between transformer cost and energy efficiency levels, referred to as a cost-efficiency schedule.

In consultation with outside experts, the Department selects the specific engineering analysis tools to be used in the evaluation. There are three general approaches for developing cost-efficiency schedules: the “efficiency level approach,” the “design option approach,” and the “cost assessment approach” (see Sect. 4.4). The critical inputs to the engineering analysis are data from manufacturers and/or experts in designing and costing transformers. This includes the cost-efficiency information available through retail prices of transformers and their existing efficiencies. However, information is also required to estimate, for some products, cost-efficiency tradeoffs that may not be available from current market information. This type of information may be developed by manufacturers, from simulation models and/or by design experts.

The cost-efficiency schedules for each product class from the engineering analysis are used in evaluations of life-cycle cost and the calculation of simple payback periods.

3.5 LIFE-CYCLE COST ANALYSIS

The effects of standards on transformer owners include change in operating expense (usually decreased) and a change in purchase price (usually increased). In rulemakings for other products, the Department has analyzed the net effect on consumers by calculating the life-cycle cost (LCC) using the engineering cost-efficiency schedule for energy consumption and equipment prices. Inputs to the LCC calculation include the installed owner cost (purchase price plus installation cost), operating expenses (energy and maintenance costs), lifetime of the product, and a discount rate. The transformer industry has commonly used a similar method called total owning cost (TOC) using A and B factors for core and load losses.

The Department plans to develop a computer spreadsheet LCC model to calculate the cost effects on distribution transformer consumers which will allow all parties to easily discern how these calculations are being made and to make their own calculations based on their own inputs. Analyses of the sensitivity of the LCC results to variations of key input parameters will also be performed.

3.6 CONSUMER SUB-GROUP ANALYSIS

While distribution transformer energy conservation standards are intended to reduce overall costs to the economy and consumers, there may be groups of consumers who see some increase in cost. The results from the LCC analysis will be used in an evaluation of the cost impacts on various consumer subgroups such as owners and operators of different types of buildings and other categories of transformer owners including utilities.

The major types of owners are electric utilities and building owners including commercial businesses, industrial operations, and other types of customers that purchase electricity at the distribution voltage and therefore own distribution transformers. Utilities own the distribution transformers that serve residential areas and the businesses that receive electricity at a voltage suitable for end-use applications.

The analysis of these subgroups of transformer owners depends on identifying characteristics related to transformer use or economics that sets the subgroup apart from other owners. The effects on these groups will be analyzed by comparing the transformer owner's capital and operating costs with and without an energy conservation standard. Life-cycle cost analysis methods will be used for consumer sub-group analysis, by modifying cost assumptions to reflect the situations of the subgroups. Factors that could result in differential impacts to subgroups include differences in energy prices and transformer loading.

3.7 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE ANALYSES

National energy savings and net present value impacts are the cumulative energy and economic effects of a transformer energy conservation standard. The impacts are projected from the year the standard would take effect through a selected number of years in the future. Energy savings, energy cost savings, equipment costs, and net present value of savings (or costs) are analyzed for each candidate standard level. The national energy and cost savings (or increases) that would result from energy conservation standards depend on the projected energy savings per transformer and the anticipated numbers of transformers sold. Base case transformer shipments projections are created that include units at various efficiency levels. The projections are based on historical information plus forecasts of market influences, national economic growth, and electricity consumption. Energy savings for various candidate standard levels are derived from the cost-efficiency schedules (Section 3.4).

The Department plans to develop a computer spreadsheet model to calculate the national energy savings (NES) and net present value (NPV), which will allow all parties to easily discern how these calculations are being made and to make their own calculations based on their own inputs.

3.8 MANUFACTURER IMPACT ANALYSIS

While transformer energy conservation standards would be intended to have overall beneficial impacts on the economy and national energy consumption, the impacts on transformer manufacturers may be adverse, beneficial, or a mixture of adverse and beneficial. The analysis of impacts on manufacturers is intended to provide the Department with an assessment of the impacts that may occur on transformer manufacturers. The manufacturer impact analysis is based on expected future cash flows. An annual cash flow analysis, which determines a total value today of future cash flows, is used as a measure of potential investment acceptability. The financial analysis will be conducted using the Government Regulatory Impact Model (GRIM) which is a computer spreadsheet. GRIM uses the following inputs:

- Estimated manufacturer costs and investments from data provided by distribution transformer manufacturers and independent consultants;
- Manufacturer list prices;
- Financial information (e.g., tax rate, working capital, depreciation, etc.) will be obtained from SEC 10-K statements, other publicly available industry statistics, and manufacturer interviews; and
- Future shipments projected by the national energy savings analysis.

In addition to financial impacts, a wide range of quantitative and qualitative effects may occur following adoption of a standard that may require changes to distribution transformer manufacturing practices. These effects will be identified through interviews with the distribution transformer manufacturers and other stakeholders (e.g., electrical contractors and distributors).

Manufacturer impact analysis results will also include estimates of employment impacts (to be used in the Net National Employment Impacts, Sect. 3.11), manufacturing capacity impacts and cumulative regulatory impacts.

3.9 UTILITY IMPACTS ANALYSIS

In addition to their economic impacts as consumers of distribution transformers, electric utilities also potentially would be affected by a reduction in net generation resulting from the increased transformer efficiency of their electricity customers who purchase their own transformers. To perform the utility impacts analysis the Department will use the BRS (Office of Building Research and Standards) version of the Energy Information Administration's (EIA) National Energy Modeling System (NEMS). NEMS (DOE 2000) is a large multi-sectoral partial equilibrium model of the U.S. energy sector that has been developed over several years by EIA, primarily for the purpose of preparing the Annual Energy Outlook (AEO).

NEMS produces a widely recognized baseline forecast for the U.S. through 2020 and is available in the public domain. Typical NEMS output includes forecasts of electricity sales and price. The utility analysis will be conducted by comparing NEMS-BRS output for various distribution transformer standard levels with the latest AEO forecasts. The assumptions used in the AEO will also serve as the basic assumptions applied to the analysis of the impacts of energy conservation standards on utilities.

3.10 ENVIRONMENTAL ANALYSIS

The major environmental effects resulting from transformer energy conservation standards would be reduced electrical energy consumption resulting in reduced environmental emissions from the operation of power plants. Analyses for previous standards have reported energy-related emissions of sulfur dioxide (SO₂), nitrogen oxides (NO_x) and carbon dioxide (CO₂). These emissions will be estimated at the national level using the NEMS-BRS model described in Section 3.9 and the results of the national energy savings analysis.

3.11 NET NATIONAL EMPLOYMENT IMPACTS

Impacts on employment from standards may be direct or indirect. Direct employment impacts would result if standards led to a change in the number of employees at distribution transformer manufacturing plants. Direct employment impacts will be estimated in the manufacturer impact analysis. Information will be developed by first asking stakeholders for input and then following up with further research. This will include a review of existing trends and determining the necessary manufacturing adjustments to achieve the candidate efficiency levels.

The Department will also attempt to estimate the indirect employment impacts. The national employment estimation derives from the national energy savings which may shift some spending by transformer owners from energy to other sectors of the economy and may affect employment in the electric utility sector.

4. ISSUES OF SPECIAL CONCERN

Many tasks must be completed to perform the analytical process described in Chapter 3. This chapter is focused on important issues that the Department must resolve to carry out this process and that appear to involve significant uncertainty. Although the Department encourages comments about any part of the analytical process, it seeks discussion and comment in particular on these issues.

4.1 TRANSFORMERS TO BE CONSIDERED

Section 346 of EPCA directs the Department to consider whether an energy conservation program for “distribution transformers” is warranted, but provides no definition for “distribution transformer.” The definition of a distribution transformer will be established in the final test procedure rule. However, as stated in Section 1.2.3 of this document, the final test procedure rule has not yet been published and, therefore, the definition is still unresolved.

As also stated in Section 1.2.3, the Department intends to assess revisions to the test procedure by means of another limited reopening of the test procedure rulemaking record. This reopening notice may include a revised definition of distribution transformers with limited exclusions. The Department also intends to address as part of the energy conservation standards rulemaking whether standards are unwarranted for particular types of distribution transformers. The following discussion relates to transformers to be considered for energy conservation standards, and included in the process for considering separate or no standards for some classes of transformers.

In its Determination, the Department considered all transformers with a primary voltage of 480 V to 35 kV, a secondary voltage of 120 V to 480 V, and a capacity of either 10 to 2500 kVA for liquid-immersed transformers or 0.25 kVA to 2500 kVA for dry-type transformers except for transformers which are not continuously connected to a power distribution system. 62 FR 54811 (October 22, 1997).

In the Test Procedure NOPR, the Department proposed to increase the secondary voltages of transformers included as distribution transformers from a range of 120 V to 480 V to a range of 120 V to 600 V and to include an electrical frequency range of 55 to 65 Hz. The exceptions were also changed with the definition of a distribution transformer proposed as “a transformer with a primary voltage of 480 V to 35 kV, a secondary voltage of 120 V to 600 V, a frequency of 55-65 Hz, and a capacity of either 10 kVA to 2500 kVA for liquid-immersed transformers or 0.25 kVA to 2500 kVA for dry-type transformers, except for (1) converter and rectifier transformers with more than two windings per phase, and (2) transformers which are not designed to be continuously connected to a power distribution system as a distribution transformer. This second exception includes regulating transformers, machine tool transformers, welding transformers, grounding transformers, testing transformers, and other transformers which are not designed to transfer electrical energy from a primary distribution circuit to a secondary distribution circuit, or within a secondary distribution circuit, or to a consumer’s service circuit.” 63 FR 63370 (November 12, 1998).

Many comments were received on this proposed definition regarding the secondary voltage and capacity ranges and requesting exclusions for various transformers including liquid-filled transformers, rectifier and converter transformers, autotransformers, transformers with tap ranges greater than 15 percent, sealed/non-ventilated transformers, special impedance transformers, harmonic transformers and some retrofit transformers.

These issues were addressed in a limited reopening notice. 64 FR 33431 (June 23, 1999). In the reopening notice, the Department stated its intention to adopt the proposed secondary voltage range of 120 V to 600 V and to increase the 0.25 kVA lower capacity limit for dry-type transformers in the test procedure final rule. Regarding the various requests for exclusions the Department stated it was inclined to exclude all rectifier and converter transformers, autotransformers and transformers with tap ranges greater than 15 percent. However, for the other requested exclusions, and for distribution transformers in general, the Department stated that it would reevaluate its determination of the transformers for which standards are warranted in the energy conservation standards rulemaking.

As stated in Section 1.2.3, in preparing the test procedure final rule, the Department has developed various concerns about the level of detail in the test procedure. We also have concerns with the portion of the proposed definition of distribution transformer that excludes certain types of transformers. For example regulating transformers, machine tool transformers, welding transformers, grounding transformers and testing transformers, contained in the definition, are themselves not defined so as to distinguish them from transformers which are designed to be continuously connected to a power distribution system and are therefore distribution transformers. The intent for which a transformer is designed cannot necessarily be derived from its possible application.

An issue for the energy conservation standards rulemaking is to determine those transformer product classes which should have separate standards or no standards. For the initial purposes of the standards rulemaking, we intend to consider the following transformers:

Transformers designed to continuously transfer electrical energy either single phase or three phase from a primary distribution circuit to a secondary distribution circuit, within a secondary distribution circuit, or to a consumer's service circuit; limited to transformers with primary voltage of 480 V to 35 kV, a secondary voltage of 120 V to 600 V, a frequency of 55-65 Hz, and a capacity of 10 kVA to 2500 kVA for liquid-immersed transformers or 5 kVA to 2500 kVA for dry-type transformers.

This initial scope of transformers to be considered would be modified as necessary by the definition of distribution transformers set forth in the test procedure final rule.

4.2 PRODUCT CLASS

Products may be separated into product classes if their capacity or other performance-related features or attributes, including those that provide utility to the transformer user, inherently affect efficiency and justify the establishment of a different energy conservation standard, or possible exemption from energy conservation standards, for products with that feature or attribute. Some of the features or attributes that might justify the establishment of product classes for distribution transformers are outlined below.

The Department often defines product classes using information obtained in discussions with stakeholders and intends to do so as part of this process. The Department seeks discussion on whether the following features or attributes affect distribution transformer efficiency and warrant separate product classes, and whether other characteristics not outlined below should be considered for defining separate product classes for distribution transformers because they affect efficiency and should be the basis for separate energy conservation standards or exemptions.

Type of insulation (liquid or dry)

Medium voltage liquid- and dry-type distribution transformers perform identical electrical functions. Although predominantly used outdoors, medium voltage liquid transformers with appropriate fluids can be used indoors. Likewise, dry transformers are predominantly used indoors but can be used outdoors with appropriate enclosures. NEMA has used liquid-type and dry-type to classify distribution transformers. The Department must determine whether there are significant differences in the utility, safety, or performance provided by liquid and dry transformers that would warrant separating them into distinct product classes for the purpose of considering separate energy conservation standards for these products. Are there other insulation-related criteria that would require the identification of other product classes?

Transformer output capacity

Distribution transformers that are otherwise similar in number of phases, voltage, and type of insulation, tend to increase in efficiency with increasing capacity. The NEMA TP-1 standard specifies lower minimum efficiencies as capacity decreases. The Department is considering how, for purposes of considering energy conservation standards, transformers should be separated into different product classes based on capacity (kVA). As one approach, efficiency might be extrapolated throughout a product class of differing capacities through use of a mathematical formula such as the “0.75 rule.”² Alternatively, there may be capacity ranges that can be grouped together.

² The “0.75 rule” holds that both the cost and the losses of transformers of similar type and technology increase as the ratio of the kVA size to the 0.75 power.

Primary voltage

Dry-type distribution transformers are typically marketed as medium voltage (primary voltage greater than 600 volt) or low voltage (primary voltage 600 volt or less). The TP-1 standard specifies different efficiency standards for dry-type transformers based on whether they are medium- or low-voltage transformers. Higher voltages require better insulation and larger spacing between conductors, both of which may reduce transformer efficiency. The Department must assess whether low-voltage transformers should be a separate product class from medium-voltage transformers.

Medium-voltage transformers include transformers with primary voltages greater than 600 V and up to 35,000 V. The Department is seeking information on whether, and if so how, this range of primary voltages should be subdivided into more than one product class.

Number of Phases

Distribution transformers have either a single phase or three phases. The Department must decide whether separate product classes should be defined by the number of phases, for the purpose of considering separate efficiency levels for such classes. To that end, the Department is seeking information on the basis for the separating single- and three-phase transformers into separate product classes.

Other

In addition, the Department is seeking information on whether there are other characteristics that should be included with those identified here. For instance, do distribution transformers designed for use in severe environments warrant a different product class? Are there other designs for distribution transformers which warrant establishment of a separate product class?

4.3 CHARACTERIZATION OF BASELINE DISTRIBUTION TRANSFORMERS

A baseline model is established as a reference point for each product class against which changes that would be brought about by energy conservation standards can be measured. A baseline model represents the characteristics of a distribution transformer of a specific product class, including operating capabilities, energy efficiency and price. Typically a baseline model would be a model that just meets required energy conservation standards. However in cases where there is no energy conservation standard, as is the case for distribution transformers, the baseline model would be the typically-sold, low efficiency model in the marketplace. After the product classes are chosen, the characteristics of the baseline model for each class are defined. The baseline model is used in the life-cycle cost and payback analyses.³ To determine energy savings and change in price, each higher efficiency design option is compared with the baseline model.

³Note that the meaning of *baseline* is distinct from the time-dynamic base case, which is used in the National Energy Savings analysis. In that analysis, the base case represents the mix of models currently on the market and, in each future year, projected to be sold in the absence of energy conservation standards.

For dry-type transformers, the Department assumes that the baseline models would be low-cost transformers designed for operation with up to a 150 degree temperature rise. The prices and efficiencies of dry type transformers are assumed to be typical of low-cost transformers used where the cost of electricity is not considered in transformer selection. For liquid type transformers, the Department assumes that the baseline models would be rated for operation with a 65 degree temperature rise, and would have the losses described by Tables 4.1 and 4.2 of ORNL-6925.⁴ The Department is seeking comments and information on the appropriate choice of baseline distribution transformer models.

4.4 ENGINEERING ANALYSIS APPROACHES

The purpose of the engineering analysis is to estimate the relationship between transformer cost and energy efficiency levels. The relationship between transformer efficiency levels and the cost of achieving these levels is referred to as a *cost-efficiency schedule*. Cost-efficiency schedules are the basis for developing economic measures such as life-cycle cost and payback period. A key question in the engineering analysis is how to get the data and information that will accurately describe this relationship.

There are three general approaches for developing cost-efficiency schedules: the “efficiency level approach,” the “design option approach,” and the “cost assessment approach” (sometimes called the *reverse engineering approach*). These approaches are explained below.

The *efficiency level approach* involves selecting a number of transformer efficiency levels and asking manufacturers to estimate the total or incremental cost of manufacturing or sales price of transformers that would achieve the specified efficiency levels. This approach would rely on manufacturers to provide an accurate representation of the costs of improved efficiency.

The primary advantages of the efficiency level approach are that manufacturers need not provide details about their manufacturing processes or costs. Further, it keeps the number of items of information requested of manufacturers to a minimum. On the other hand, because very detailed information about manufacturing costs are needed for the MIA, the savings of effort for manufacturers may not be significant.

The principal disadvantage of this approach is that, because the designs and components of energy efficiency improvements would not be known, it could be difficult to verify the accuracy of the information received from the manufacturers. The inability to verify information received would lead to greater uncertainty about the costs of distribution transformer efficiency improvements.

The *design options approach* involves selecting technology and/or material options for alternative transformer designs and requesting that manufacturers provide estimated costs of transformers built with these design options. This approach involves close interaction between manufacturers and the Department (and/or its contractors). With this approach, the Department selects the design options (after consultation with knowledgeable parties) that

⁴“Supplement to the ‘Determination Analysis’ (ORNL-6847) and Analysis of the NEMA Efficiency Standard for Distribution Transformers,” Oak Ridge National Laboratory, Oak Ridge, Tennessee, September 1997.

warrant consideration and asks manufacturers to estimate the costs of producing the transformer. The strength of this approach is in gaining a better understanding of the technological and economic basis of efficiency improvements. A weakness is that the transformer design process is not fully integrated with any specific manufacturer as it would be in the efficiency level approach. Thus, a manufacturer may know how to produce a more cost-effective high-efficiency transformer than selected as a design option by the Department. The types of parameters for design options that would be considered include: core materials; core designs, cross-sections and dimensions; insulation materials; and windings. This approach also requires the Department to model the efficiency improvements resulting from the design options being considered.

The *cost assessment approach* (also known as the reverse engineering approach) is the most detailed in that it builds the cost of manufacturing a transformer from scratch by estimating the costs of manufacturing various models of transformers. This approach is expected to be a valuable tool for supplementing the efficiency level or design option approaches. However, the cost and time required for designing and developing manufacturing plans for a number of transformer designs would be high.

Using the cost assessment approach for a few specific designs may be more manageable, but it is not clear how this approach would allow bridging from a small number of designs to the substantial number of designs in use in the present marketplace.

The Department will assess and select an engineering analysis approach to be used for distribution transformers. To that end, the Department seeks comments and suggestions on the approach(es) that should be taken for developing the cost-efficiency schedule. This includes input on what approach(es) are most practical. The Department also seeks comments on methods for extrapolating the cost-efficiency schedule over transformer size ranges. For example, the available information shows that both the cost and the losses of transformers of similar type and technology increase as the ratio of the transformer capacity (kVA) to the 0.75 power.

4.5 RETAIL PRICES AND MARKUPS

Transformer prices are required for input to life-cycle cost and payback analyses. These prices are difficult to observe for several reasons. Unlike many retail appliances, the prices of transformers are highly negotiable; the prices listed in manufacturer catalogues are often more than twice the price that is customarily paid. Therefore price quotes from distributors or manufacturers must be carefully analyzed so that they represent realistic markups. Prices are also difficult to observe because transformers are usually purchased by an electrical contractor who charges the ultimate owner a fixed price for the transformer and its installation. Furthermore, transformers are often bundled with other electrical equipment as part of a building's electrical system.

The Department will estimate prices for distribution transformers and solicits information on approaches and data sources for estimating average retail prices of distribution transformers. The following are some of the questions the Department will assess. Can retail prices be adequately represented by data on manufacturers' average costs plus a standard markup? Should there be a markup for both distributors and contractors? What are reasonable markups? What factors influence markups?

4.6 TRANSFORMER DESIGN LOADS AND OPERATIONAL LOADING

Transformer energy losses are affected by both the construction of the transformer and its loading. While improvements to transformer efficiency are the focus of this rulemaking, estimating the energy and cost savings of improved transformer efficiency requires knowledge of transformer loading in the field.

The Department's review of the literature indicates that, outside of electric utilities, publicly available studies of distribution transformer loading are few. There appear to be discrepancies between various estimates of transformer loading. For example, the NEMA TP-1 voluntary standard specified that transformer efficiency should be evaluated at a load equal to 50% of the transformer's rated capacity for medium-voltage transformers, and at 35% of rated capacity for low-voltage transformers. By contrast, the largest study of loads on low-voltage transformers the Department is aware of found average loadings of about 16% of rated capacity.⁵ In addition, analysis of FERC Form 1 data by ORNL indicates that most utility distribution transformers, which are classified as medium-voltage transformers, are loaded on average between 20 and 30% of rated capacity.

Because transformers are designed to operate most efficiently at a particular load and the extent to which actual loading matches design loads is not well known, the Department is contemplating requesting manufacturer cost estimates for transformers designed for a range of loading levels. The Department seeks comments on: (1) the distribution of design loads; (2) available data on actual loading; (3) methods for collecting additional data on both design loads and actual loading; and (4) the extent to which manufacturer cost estimates are available, or can be obtained, for a range of loading levels.

The Department solicits information and comments that would help establish the typical average and peak loads on distribution transformers of all sizes and types.

⁵"Low-Voltage Transformer Loads in Commercial, Industrial, and Public Buildings," The Cadmus Group, Waltham, Massachusetts, December 7, 1999.

4.7 BASE CASE

In order to evaluate the various impacts of candidate energy conservation standards, the Department must develop a base case to compare against. The base case is designed to depict what would happen to energy consumption and costs over time if DOE does not adopt energy conservation standards. The base case is predicated on transformer shipments, the mix of transformer efficiencies sold in the absence of standards and how that mix would change over time. To determine the base case, the Department needs data on transformer shipments, the market shares of the different efficiency levels offered for each product class, market trends on shipments and how these market shares are changing.

To the extent that other programs and initiatives seem likely to affect the future mix of transformer efficiency levels, the effects of these approaches will be considered in developing the base case. The Department intends to include current regulations (e.g., state) and non-regulatory programs in the base case for the national energy savings analysis. These other approaches will be evaluated to determine whether they are currently affecting efficiency levels of distribution transformers and whether they are likely to affect future transformer efficiency levels. The Department must collect information and data relevant to such approaches to permit such an analysis. The information and data that are needed include, but are not limited to, the identity, scope, penetration, and effectiveness of such initiatives, as well as their impact on the market share of more efficient transformers.

The Department has identified the following existing activities that are intended to increase the efficiency of distribution transformers:

- The National Electrical Manufacturers Association TP-1 voluntary standard,
- The ASHRAE 90.1 building code (e.g., the Department and others have proposed that NEMA's TP-1 voluntary standard be incorporated into the ASHRAE 90.1 building code),
- Education and promotion (e.g., the Environmental Protection Agency's Energy Star® Transformers program and the Consortium for Energy Efficiency's High-Efficiency Commercial and Industrial Transformers Initiative).
- State regulations
- Utility rebates

5. BACKGROUND ON DISTRIBUTION TRANSFORMERS

Distribution transformers are used to deliver electric power as part of an electrical distribution system. From power plants, electrical energy is delivered to consumers by transmission and distribution systems. Transmission systems transmit power at high voltages (69 to 765 kV) that allow electricity to be transmitted long distances with low losses. Near load centers (areas where electricity is consumed), distribution transformers reduce voltages to distribution voltages (4 to 35 kV) which distribution power lines carry to the buildings where it is used. Outside the buildings, *medium voltage distribution transformers* convert the electricity to lower voltages (120 to 600 V) that can be used in power consuming equipment. Most familiar appliances and small electrical devices use single-phase electricity at 110 V, but most large electrical equipment uses three-phase electricity at higher voltages such as 480 V or higher. Inside buildings, where electricity is used at two or more voltages, electricity is often distributed within the building at 480 V (or higher) and converted to lower voltages (usually 110 V) by additional *low-voltage distribution transformers*. In this way distribution transformers are the final link in the series of electrical components that deliver electric power from a central generating source to its ultimate application.

Because they are an essential link in providing electricity to its end use, distribution transformers process essentially all electricity that is utilized. This provides an important distinction from other categories of electric appliances such as lighting devices, air conditioners, and water heaters, which utilize only a fraction of total electricity. Furthermore, where low-voltage distribution transformers are used electricity passes through more than one distribution transformer. Because they process essentially 100% of electricity consumed, the combination of all the individually-small energy losses from distribution transformers constitute a significant fraction (about 2 to 3 percent) of electrical energy generated in the United States.

Electric utilities (owners of about three-fourths of the distribution transformers in the U.S.) use medium-voltage distribution transformers to deliver power to most of their customers at voltages of 120 to 240 V which is used in electrical equipment such as refrigerators, lights, and air conditioners. However, many large electricity consumers, such as large industrial and commercial facilities, purchase electricity at distribution voltages (4 to 35 kV) and operate their own distribution transformers which provide the necessary end-use voltages. Like utilities, they must purchase distribution transformers and pay for the energy that the transformer loses.

Distribution transformers for the most part are over 95% efficient with some reaching efficiencies of over 99%. However, because of the large amounts of energy that flow through these devices, annual losses are estimated to be about 140 billion kWh (Barnes, et al. 1997). Since essentially all electrical energy is processed by transformers, even small improvements in efficiency can result in large national energy savings. For instance, based on total sales of electricity in the U.S. in 1998, an average distribution transformer efficiency improvement of one tenth of one percent (0.1%) for all transformers in the U.S. would have saved at least 3 billion kWh annually. This savings estimate assumes that all electricity sales go through only one distribution transformer while, in fact, some end user electricity goes through two or more distribution transformers. (Three billion kWh is equivalent to the electricity produced annually by a 500 MW power plant operating at a 68% capacity factor.) A previous study by the

Department of Energy found that efficiency improvements could save over 2 quads of energy over 30 years with transformer improvements having a 3 year payback period (Barnes et al. 1997). Even larger cost-effective savings appear to be feasible, because a 3 year payback period is well within the transformers expected service life, with utility transformers having average lives of approximately 32 years.